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L. F. Resolved Component Indicator Model No. VP 253

THE SOLARTRON ELECTRONIC GROUP LTD
Thames Ditton, Surrey, England

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L.F. RESOLVED COMPONENT INDICATOR

MODEL VP253

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SOLARTRON ELECTRONIC GROUP LIMITED,
SOLARTRON WORKS,
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SURREY.

VP253

L.F. RESOLVED COMPONENT INDICATOR

MODEL VP253

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Section 3	Principle of operation
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SECTION 1

INTRODUCTION

Of recent years there has been an increased tendency to employ closed loop feedback control, this tendency being equally apparent in the fields of mechanical, electrical and electronic engineering. Whatever the field of application, the designer is, in almost every case, faced with the same basic problem, namely: that of providing the stiffest possible control over the working frequency range consistent with freedom from oscillation or under-damped response, outside the working frequency range. Such design work demands a full knowledge of the transfer function of each element employed in the control loop.

The usual method of transfer function determination is to excite the unit under test at a number of fixed frequencies covering the interested frequency range, using a constant input amplitude. The output amplitude and phase angle is noted in each instance, and these results are then recorded on polar co-ordinated paper to form what is now universally known as a Nyquist diagram. The Resolved Component Indicator is ideally suited to this method of measurement. Provision is made for two input voltages - one is known as the reference voltage, and the other as the signal voltage. Two 6" scale-length meters are provided, and the function of these is to separately indicate, in terms of true voltage, the resolved components of the signal input which are "in phase with" and "at 90° to" the reference input voltage. This resolved component presentation permits direct plotting of a Nyquist diagram on ordinary linear graph paper, thus eliminating the need for polar co-ordinate paper.

A very important feature of the Resolved Component Indicator is that the meter indications are to a first order, independent of harmonic or spurious frequency content of the signal voltage, providing the reference voltage employed is itself free from such quantities.

There is scope for application of the Resolved Component Indicator wherever phase conscious measurement is required over the frequency range 0.5 c.p.s. to 1 K.c.p.s., e.g. transformer testing, dynamic balancing, simulator circuits, magnetic core material comparison tests, etc.

SECTION 2

PERFORMANCE SPECIFICATION

(1) General: This instrument will indicate, by means of two centre-zero 6" scale meters, the resolved components of a signal voltage with respect to the applied reference energisation.

(2) Frequency Range: Nominal range 0.5 c/s. to 1 Kc/s.

(3) Accuracy of Indication: ± 3% of full scale on all ranges.

(4) Signal Voltage Ranges: Full scale ranges of 50mV, 150mV, 500mV, 1.5V, 5V, 15V, 50V and 150V with either balanced or unbalanced input.

(5) Signal Input Impedance: 1M Ω unbalanced
2M Ω balanced

(6) Reference Input: Four phase reference energisation is required, each phase having a level of 10 volts r.m.s. with respect to earth.

(7) Reference Input Impedance: 1.33MΩ per phase.

(8) Harmonic and Unrelated Frequency Discrimination: Better than 40 db.

(9) Mains Requirements: 90-130V and 200-240V 40/60 c/s. with a total consumption of 210 V.A. (190 watts).

(10) Presentation: Standard rack panel 19" x 10½" high, but mounted in a "Solartron" bench type case.

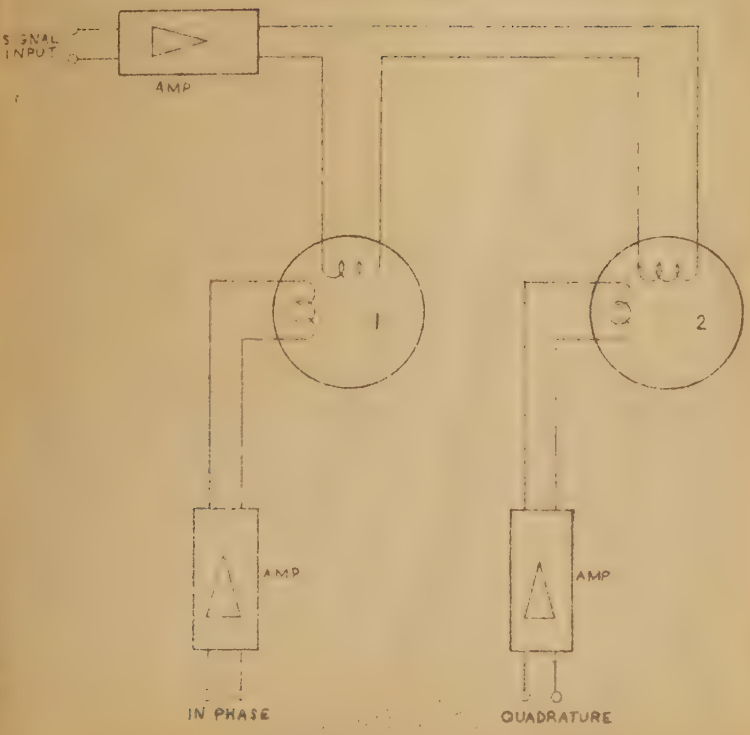

FIG. 1

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	TITLE –	
DRN	LGKS	DRG No A 14054
CHKD		SHEET 1 of 4

PRINCIPLE OF OPERATION

The Resolved Component Indicator is a device which will indicate the relative phase and amplitude of one voltage with respect to another.

The arrangement, shown in outline, in Fig. 1, is used in the Resolved Component Indicator.

Two wattmeters are employed and, for the purpose of initial explanation, these will be considered as conventional coil type dynamometer wattmeters. The voltage coil of the first meter is fed with the amplified reference voltage, and the voltage coil of the second wattmeter is fed with a voltage of identical amplitude but removed 90° "in phase". Both current coils are fed with current which is in phase with the applied signal voltage.

The moving coil of wattmeter 1 will, at any instant, be subject to a torque which is proportional to the product of the voltage and current present in the appropriate coils.

These components are, in turn, proportional to the applied reference and signal components respectively, hence the ultimate indication of the wattmeter may be written

$$\text{Indication} = \frac{K}{t} \int_0^t V_r . V_s \, dt.$$

where V_r is the reference voltage,
V_s is the signal voltage,
K is a constant,
t is time (long compared with either periodic time).

If V_r is of the form sin ωt, the above integral over long term will be zero for all forms of V_s other than $V_s = A \sin \omega t$

where A is a constant.

Hence, when a reference voltage of sine wave form is used, the meter will not respond to quadrature, harmonic or unrelated frequencies in the signal voltage. Further, if the reference voltage be maintained at constant value, the indication will be directly proportional to the component of the signal voltage which is in phase with the reference voltage.

Wattmeter , shown in Fig. 1, has its voltage coil supplied at 90° phase shift to the reference voltage, and consequently will respond only to the quadrature component of the signal input.

Conventional coil type dynamometer wattmeters have the following disadvantages for use in The Resolved Component Indicator.

1) Require substantial energising power;

2) Restricted frequency range;

3) Rather bulky and unwieldy.

The L.F. Resolved Component Indicator, therefore, employs thermocouple type wattmeters which, in addition to being 6" scale panel mounting instruments, have a greatly reduced power consumption and can quite adequately cope with 0.5 c/s - 1 kc/s. frequency currents. Other advantages are:-

1) Direct measurement of resolved components with good accuracy;

2) High degree of rejection for harmonics and unrelated frequencies.

The main disadvantage is that safety circuits are necessary to protect the thermocouple wattmeters against overload.

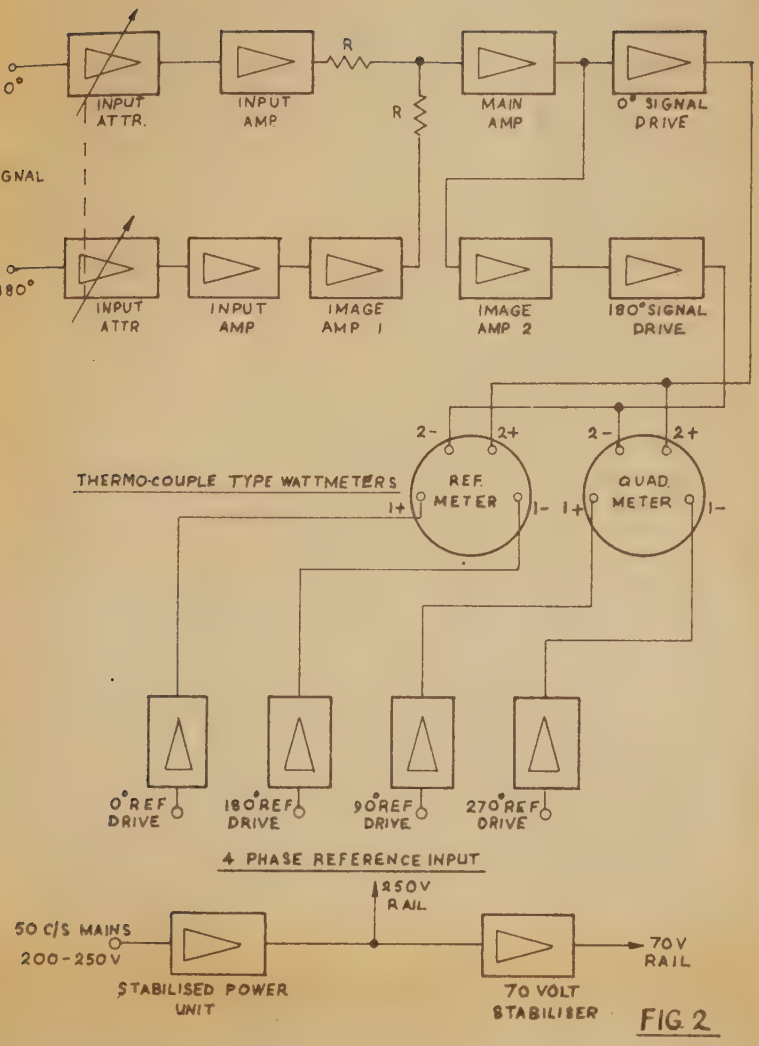

FIG. 2

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CHKD.		SHEET 2 of

BLOCK OUTLINE OF THE L.F. RESOLVED COMPONENT INDICATOR

Fig. 3 illustrates in block diagram form the various component circuits which together constitute the Resolved Component Indicator.

The whole system is concerned with feeding the two indicating meters with the correct electrical quantities. It is, therefore, necessary at this stage to examine the meters in more detail; this examination, however, will be confined to requirements and sensitivity, and will not consider functional technique.

The thermocouple wattmeter in this application should be considered as a current meter than a power measuring device. This conception is readily grasped by visualising a conventional D.C. wattmeter fed with a constant voltage at the voltage coil. Such an arrangement would then constitute a D.C. milliammeter as viewed from the current coil terminals. Now, applying this conception to the meters shown in Fig. 3, they are designed for a constant current of 10mA fed through terminals 1+ and 1-, and, when so energised, they have a current sensitivity of 5mA full scale as viewed from terminals 2+ and 2-.

The function of the 0° and 180° reference drive amplifiers is to supply a balanced drive current of 10mA through terminals 1+ and 1- of the reference meter for a nominal input of 10 volts per phase. Similarly, the 90° and 270° reference drive provides quadrature energisation for the quadrature meter.

The input attenuator has two identical sections, one for each input channel. It is a ladder attenuator of 1MΩ resistance and provides half decade steps (10dB approx.), and is arranged so that the voltage presented to the input amplifier is less than 5mV. When the instrument is used to measure unbalanced signals, the 180° input system is shorted out by a switch.

The input amplifiers are identical, and each has a fixed voltage gain of the order of 17 times. The 180° input amplifier is followed by an image amplifier which is purely a phase inverter. When a balanced signal is applied, the output of the 180° input system is added to that of the 0° input system in the resistor R adding chain. The net result is that the indication for a balanced input of x volts per phase is twice that for an unbalanced input of x volts.

The main amplifier has a preset voltage gain of approximately 20 times.

Image Amplifier 2 provides phase inversion which feeds the 180° signal drive amplifier. The two signal drive amplifiers provide balanced drive which will deliver 1mA into terminals 2+ and 2- of both reference and quadrature meters, i.e. full scale for either meter, depending on the phase of the input signal.

The blocking time constants used in the signal system are a compromise between hum and permissible phase shift in the instrument. To compensate for phase shift in the signal channel due to these components, the blocking time constant used in the reference amplifiers is arranged to give an approximately equivalent phase shift. The net overall error is negligible in the working frequency range of the instrument.

The H.T. requirements for the instrument are met by a hard valve regulated power supply which delivers approximately 100mA at 250V. and has an AC source impedance of less than 1 over the working frequency range. A low voltage rail at 75 volts is also required at low source impedance. This is obtained by means of a further stabilising system operating directly from the 250 volt rail.

The low frequency limit of the instrument is 1.5 c/s., and to handle this frequency the amplifiers would ideally be directly coupled, but D.C. amplifiers, having unstabilised heater supplies, have a fundamental characteristic, in that a 10% change in heater voltage gives an effective grid-cathode signal of 0.1 volt. The total voltage gain present in the L.F. Resolved Component Indicator is of the order of 350 times. It will be seen that, if the Instrument were a D.C. system throughout, a 10% heater variation would result in a change in quiescent level on the drive cathodes of 35 volts. This would be an impossible stage of affairs. One solution is to provide a stabilised heater supply; another, used in the Resolved Component Indicator, is to split up the voltage gain into units which are interconnected by large time constant RC couplings. Individual amplifiers in the Resolved Component Indicator are D.C. amplifiers, but their voltage gains are relatively small and heater voltage variations are thus negligible.

CIRCUIT ANALYSIS

For the purpose of operational description, the circuitry of the L.F. Resolved Component Indicator has been grouped as follows:-

1) Thermocouple type wattmeter

2) 0° Input Attenuator

3) 0° Input Amplifier

4) 180° Input Attenuator

5) 180° Input Amplifier

6) Image Amplifier 1

7) Main Amplifier

8) Image Amplifier 2

9) 0° Signal Drive

10) 180° Signal Drive

11) Reference 0° and 180° Drive Amplifiers

12) Reference 90° and 270° Drive Amplifiers

13) Stabilised Power Supply

14) 70 volt Rail

Each circuit section listed above will be examined with reference to circuit diagram D/253/C1, which will be found at the end of this handbook.

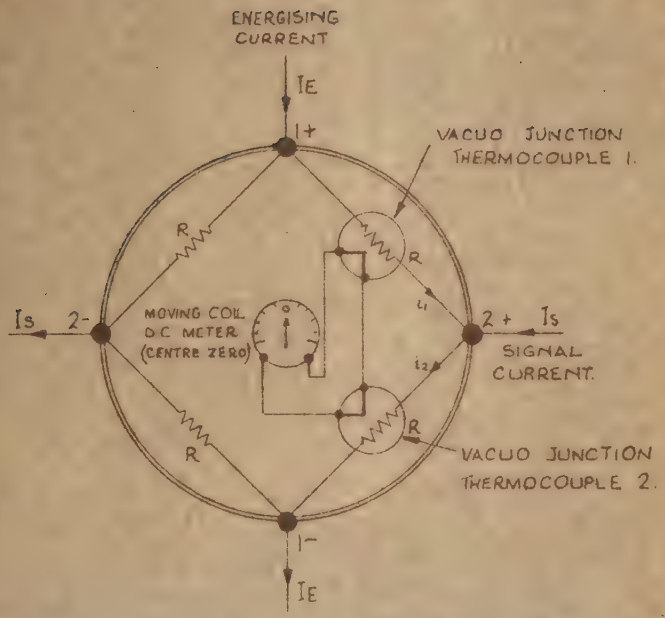

FIG 3.

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(1) THERMOCOUPLE TYPE WATTMETER

The thermocouple wattmeter arrangement employed in the Resolved Component Indicator comprises 3 fixed resistors, 2 vacuo-junction thermocouples, and a D.C. moving coil meter. The fixed resistors and vacuo-junction thermocouples are housed in the meter case, and the overall assembly is provided with 4 input terminals - see Fig. 3.

The fixed resistors and thermocouple heaters are all of equal resistance, but the value of this resistance may vary between 90 and 120Ω.

The fixed resistors and the thermocouple heaters are connected in Wheatstone bridge form, and the thermocouples are connected in series opposition to feed the moving coil meter.

The behaviour of this system will first be considered with the application of D.C. currents.

Assume an energising current I_E fed into terminal 1+ and out of terminal 1-. A current of $\frac{I_E}{2}$ will thus flow through each vacuo-junction heater, with the result that equal temperatures are obtained, equal e.m.f.'s produced, and thus no deflection obtained on the indicating meter.

Similarly, if a current I_S flow is applied, no indication is obtained on the meter.

Now, consider the effect of simultaneous application of currents I_E and I_S. Let I_E = 10mA and I_S = 2mA, where I_E flows into 1+ and I_S flows into 2+.

The individual currents in the vacuo-junction heaters will thus be:-

$$i_1 = 5 - 1 = 4 \text{ mA}$$

$$i_2 = 5 + 1 = 6 \text{ mA}$$

A meter indication will, therefore, be obtained by simultaneous application of direct currents.

The response of the system will now be examined in more detail for the application of alternating currents.

(1) contd.

It will be assumed that the thermocouple e.m.f. is proportional to the average heating effect, hence:-

$$e = K_1 \int i^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (i)$$

where e = thermocouple e.m.f.; K_1 is a constant;

i = instantaneous heater current.

The meter indication, which is proportional to the difference of the thermocouple e.m.f.'s, may therefore be written:-

$$\text{Indication} = K_2(e_2 - e_1)$$

where e_1 and e_2 are the e.m.f.'s of the corresponding thermocouples and K_2 is a constant.

Substituting from (i) above, this may now be expressed:-

$$\text{Indication} = K_3\left(\int i_2^2 - \int i_1^2\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (ii)$$

From Fig. 3:-

$$i_2 = \tfrac{1}{2}(I_E + I_S)$$

$$i_2^2 = \tfrac{1}{4}(I_E^2 + I_S^2 + 2\, I_E I_S)$$

similarly

$$i_1^2 = \tfrac{1}{4}(I_E^2 + I_S^2 - 2\, I_E I_S)$$

Substituting in (ii) above:-

$$\text{Indication} = \frac{K_3}{4}\left(\int I_E^2 + \int I_S^2 + 2\int I_E I_D - \int I_E^2 - \int I_S^2 + 2\int I_E I_S\right)$$

$$= K_3 \int I_E I_S$$

The above expression is the basic equation of response for a wattmeter.

(1) contd.

The direct proportionality between thermocouple e.m.f. and heating effect, mentioned in paragraph (1), is of practical value to a first order. Further, the characteristics of the two thermo-junctions employed are never absolutely identical, despite careful selection. The overall performance will, therefore, be taken as approximating to that of a conventional instrument. However, when a constant compensation current is employed, as in the case of the Level Component Indicator, the approximation is very close.

(2) 0° INPUT ATTENUATOR

The input attenuator is a simple ladder attenuator, having a constant input resistance of 1MΩ, but having an output impedance which varies according to the setting. Steps of approximately 10db are provided up to a maximum of 70db.

Two switch wafers are employed for convenience of construction, each position being [illegible] by means of direct soldering between the corresponding tags of the two wafers.

High stability carbon resistors, having a tolerance of ± 1%, are employed throughout.

The [illegible] employed for [illegible] Shorting on the input has a capacitance between foil and case of approximately 200pF. If the case were mounted directly on the chassis, this capacitance would shunt the input, producing undesired phase shifts; to obviate this, the case is mounted on a block of insulating material. The capacitance between foil and earth is thus reduced to approximately 40pF. This somewhat large value still exists, because of the necessity of shielding the capacitor and input circuits which may have to operate at relatively low level.

When a signal is applied which has a large quiescent content, a temporary paralysis will occur in the instrument, due to the large time constants employed. This paralysis time can be shortened, if the instrument attenuator is switched to the PRIME position. In this position, the input time constant is reduced by shunting the 1MΩ attenuator with 1KΩ, and the grid of the input amplifier is grounded. After switching to PRIME, the attenuator is returned to the required sensitivity.

(3) 0° INPUT AMPLIFIER

The pentode V1 and double triode V2, together with their associated components, comprise the 0° input amplifier.

This amplifier employs a "ring of three" i.e. two amplifying stages and a cathode follower with negative feedback from the output to the first cathode. This amplifier is D.C. coupled and thus does not have the large open gain one usually associates with rings of three.

The 6BS7 valve, chosen for low noise and hum properties, is triode connected. A forward gain of 16.7 is taken from the amplifier, leaving about 20db of negative feedback.

A separate heater winding is provided for the two valves in the input amplifier, in order that a hum-balancing potentiometer may be employed to ensure minimum hum introduction on the high impedance input stage.

RV1 and R12 are included, in order to give a variation in D.C. levels throughout the circuit. This variation may be needed to compensate for change of input valve. The output cathode of V2 is normally set to 70V quiescent.

(4) 180° INPUT ATTENUATOR

This attenuator is similar to the 0° input attenuator, but has a toggle switch which shorts the input to ground when the instrument is used in the "UNBALANCED" condition.

(5) 180° INPUT AMPLIFIER

This amplifier is identical with the [illegible] input amplifier.

(6) IMAGE AMPLIFIER 1

This consists of double triode V7, the first half being used as an amplifier stage coupled to the second half a cathode-follower. It has 100% negative feedback and so gives close [illegible], of approximately unity. [illegible] determined by the values of R66 and R68. R67 provides bias for the first half triode.

R15, R74, RV6 comprise a resistor adding system such that, when a balanced signal "A-B" is applied, the output of the image amplifier is equal to the output of the input amplifier, thus producing an indication which is twice that of an unbalanced signal "V".

The whole system of input amplifiers, image amplifier and adding network completely remove the effect of any unbalance there may be in the balanced signal.

(7) MAIN AMPLIFIER

The amplifier is again a "pair of three", comprising two triode amplifying stages followed by a cathod follower. The circuit is similar to the input amplifier, but the second triode is directly coupled to the first, thus eliminating one "divide down" again. The forward gain, nominally of the order of 80, is variable by means of potentiometer RV3. The change in D.C. levels, necessary to allow for valve change, is catered for by R72, R73, RV4. The output cathode of V6 is set at 70 volts quiescent.

The case of capacitor C5 is mounted on the framework, and the capacity between the foil and the case thus becomes effectively capacity to ground on the input to this amplifier. As the amplifier is fed from the relatively high source impedance of the adding network, a lagging phase shift will result. A measure of compensation is achieved by the inclusion of VC1, which introduces a leading phase shift.

Resistor R187 is included to prevent the foil-case capacity of C8 from loading the cathode follower of the main amplifier and introducing parasitic oscillation.

(8) IMAGE AMPLIFIER 2

This amplifier is substantially identical with Image amplifier 1.

(9) 0° SIGNAL DRIVE

Again, this is a "ring of three" D.C. amplifier. It has 100% negative feedback, and thus has a forward gain which is very close to unity. As the stage is required to drive the signal circuits of the thermocouple wattmeter, the output stage is an E/F valve used as a cathode follower.

A thermocouple wattmeter, unlike a conventional wattmeter, does not have electrical isolation between its two input circuits. It is, therefore, essential that steps be taken to prevent cross-feed of current between the two driving sources. The necessary isolation is normally achieved by utilising transformer coupling but, in the case of the Resolved Component Indicator, this would demand a transformer relatively free from phase shift over the frequency range 0.1 c/s. to 1 Kc/s.

The arrangement chosen for the Resolved Component Indicator is that of balanced voltage drive on both phase circuits, such that the meter is maintained at a virtual earth. Consider the application of drive voltage to terminals 2+ and 2-. As this voltage is balanced about earth and the circuit itself is symmetrical, the terminals 1+ and 1- of the wattmeter will be at virtual earth potential. Consequently, no current will flow in the drive circuit for terminals 1+ and 1-.

When drive voltage is applied to both circuits simultaneously, a certain amount of unbalance, and hence crossfeed, will result, due to the unequal voltage drops in the individual wattmeter arms. This crossfeed is considerably reduced by the resistance in series with the meter terminals.

The balanced drive voltages in the actual circuit are symmetrical, not about earth but about a quiescent potential of 70 volts, thus avoiding the need for a negative voltage rail.

Resistors R182, RV17, R183 and R185, RV18, R184, provide a means of neutralising small unbalance errors in the wattmeter elements.

When an input voltage in excess of the normal working value is applied to the signal channel, the cathode followers V11 and V13 limit the meter overload current by means of cut off and grid current action on the negative and positive half cycles respectively. The resistor R165, in series with both anode circuits, has the effect of reducing the quiescent anode potential without introducing source impedance, due to the balanced action of the cathode followers. The inception of grid current can thus be controlled by choice of R165.

The capacitor C45, which decouples the above-mentioned resistor to H.T. negative, has negligible effect over the working frequency range, but suppresses a parasitic mode.

Capacitor C10 and Resistor R40 also suppress a parasitic mode in the amplifier.

(10) 180° SIGNAL DRIVE

The 180° signal drive amplifier is identical with the 0° signal drive.

(11) REFERENCE 0° AND 180° DRIVE AMPLIFIERS

For reasons similar to those described in sub-section (3) above, the 2μF D.C. blocking capacitors have their cases insulated from chassis. There is, however, in view of the level at which these amplifiers work, no need to shield these capacitors. The grid leak R102 is chosen in value so that, together with C22, the time constant in the reference drive system is approximately equivalent to the sum of the time constants in the signal system, for reasons stated in section (3). The circuitry of this amplifier is identical with that of the 0° signal drive, apart from R112 which is greater in value than its counterpart. This greater value is used to reduce quiescent cathode follower current, as the reference drive stages do not have to deliver as much power as the signal drive.

(12) REFERENCE 90° AND 270° DRIVE AMPLIFIERS

This system, which energises the quadrature meter, is identical with the 0° and 180° system, apart from the inclusion of RV13 which enables the sensitivity of the quadrature indication to be adjusted to be equivalent to that of the reference indication.

(13) STABILISED POWER SUPPLY

In order to avoid completely the use of electrolytic capacitors, the Resolved Component Indicator has been designed throughout without employing tuned circuit decoupling. It is, therefore, essential that the H.T. supply be of very low source impedance and, further, that the hum and noise level on the H.T. line be of an extremely low order.

The Resolved Component Indicator power pack has an A.C. source impedance of approximately .2Ω, and the total hum and noise level over a 500 Kc/s. bandwidth is in the order of 500μV.

The system employed to obtain the above performance is very similar to a conventional hard valve stabiliser, but utilises two stages of amplification within the control loop, in place of the usual single stage. The stabilised output voltage is delivered at the cathode of series pass valve V12. A proportion of this voltage is applied to the control grid of V11, the cathode of which is maintained at 150V by the reference tube V13. The amplified error signal from V11 anode is cathode follower coupled into the cathode circuit of a further amplifier, the double triode V10 providing both the cathode follower and the second amplifier. The output from the second amplifier anode circuit is then used to control the series valve. The resistance coupling chain fulfils the two further functions of supplying the first amplifier screen grid and giving a variable potential for the second amplifier control grid.

The Resolved Component Indicator power pack should not be used at output currents of less than about 70 m.a., as under such conditions a very high degree of negative bias is required for the series valve, and in giving this bias the second amplifier (V10) will take grid current and the performance of the pack will deteriorate. Should it be necessary, for test purposes, to disconnect a high proportion of the H.T. loading, a ballast resistor of suitable value should be connected in its place.

(14) 70 VOLT RAIL

The 70 volt rail is obtained by means of a hard valve stabiliser system operating from the 250 volt rail.

Once again, a "ring of three" circuit is used, which has its input grid registered from the 250V rail. The overall feedback is 100% negative, but there is positive feedback within the loop. As the ring is a D.C. amplifier, its output voltage is set by potentiometer RV12 which adjusts the voltage on the input grid.

The two combinations C39, R160 and C48, R186 eliminate [illegible] modes in the system.

[illegible] rail is not called upon to deliver current, in fact, it [illegible] current of approximately 1mA from the Resolved Component [illegible].

The A.C. source impedance of the rail is in the order of 2Ω.

COMPONENT LISTS

This information is grouped as follows:-

Resistors (fixed)

Resistors (variable)

Capacitors

Valves

Special Components

NOTE:

No information is supplied with regard to valveholders, switches, fuseholders, etc.

RESISTORS [illegible]

Circuit [illegible]	Value [illegible]	[illegible] ±	Manufacturer's [illegible] No.	[illegible]
R1	67K	1%	108	Erie
[illegible]	[illegible]	1%	108	Erie
[illegible]	[illegible]	1%	108	Erie
[illegible]	[illegible]	1%	108	Erie
[illegible]	1.47K	1%	108	Erie
[illegible]	[illegible]	1%	108	Erie
[illegible]	[illegible]	1%	108	Erie
[illegible]	[illegible]	1%	108	Erie
[illegible]	[illegible]	1%	109	Erie
R10	[illegible]	2%	109	Erie
R11	[illegible]	2%	109	Erie
[illegible]	[illegible]	5%	73	Painton
[illegible]	[illegible]	2%	109	Erie
R14	[illegible]	1%	109	Erie
[illegible]	[illegible]	1%	109	Erie
R16	270K	1%	109	Erie
R17	22	10%	9	Erie
R18	1.6M	1%	100	Erie
R19	1M	1%	108	Erie
[illegible]	[illegible]	1%	108	Erie
R21	[illegible]	1%	109	Erie
[illegible]	[illegible]	1%	108	Erie
R23	[illegible]	2%	109	Erie
R24	[illegible]	1%	109	Erie
R25	[illegible]	2%	108	Erie
R26	[illegible]	1%	100	Erie
[illegible]	[illegible]	1%	109	Erie
[illegible]	[illegible]	10%	9	Erie
[illegible]	[illegible]	1%	109	Erie
R30	[illegible]	1%	100	Erie
R31	[illegible]	10%	9	Erie
R32	[illegible]	1%	108	Erie
R33	[illegible]	1%	108	Erie
R34	[illegible]	2%	109	Erie
R35	[illegible]	5%	109	Erie

RESISTORS FIXED:

Circuit ref.	Value -Ohms	Tolerance ±	Manufacturer's Type No.	Manufacturer
R36	270K	1%	109	Erie
R37	620K	5%	108	Erie
R38	2.7K	5%	109	Erie
R39	510K	5%	109	Erie
R40	1K	10%	9	Erie
R41	1M	1%	108	Erie
R42	2.2K	1%	P406	Palnut
R43	1.6M	1%	100	Erie
R44	220	10%	9	Erie
R45	22	10%	9	Erie
R46	1.3K	1%	108	Erie
R47	1.3K	1%	108	Erie
R48	667K	1%	108	Erie
R49	233K	1%	108	Erie
R50	66.7K	1%	108	Erie
R51	23.3K	1%	108	Erie
R52	6.67K	1%	108	Erie
R53	2.33K	1%	108	Erie
R54	667	1%	108	Erie
R55	333	1%	108	Erie
R56	220K	2%	109	Erie
R57	220K	2%	109	Erie
R58	2.2K	1%	109	Erie
R59	66K	5%	73	Palnut
R60	220K	2%	109	Erie
R61	270K	1%	109	Erie
R62	22	10%	9	Erie
R63	1.6M	1%	100	Erie
R64	47K	1%	109	Erie
R65	1M	1%	108	Erie
R66	100K	1%	109	Erie
R67	2.2M	10%	9	Erie
R68	110K	1%	109	Erie
R69	270K	1%	109	Erie
R70	22	10%	9	Erie

RESISTORS FIXED:

Circuit ref.	Value -Ohms	Tolerance ±	Manufacturer's Type No.	Manufacturer
R71	1.6M	1%	100	Erie
R72	47K	10%	9	Erie
R73	1M	1%	108	Erie
R74	9.1K	5%	109	Erie
R75	2.2M	10%	9	Erie
R76	100K	1%	109	Erie
R77	110K	1%	109	Erie
R78	270K	1%	109	Erie
R79	22	10%	9	Erie
R80	1.6M	1%	100	Erie
R81	100K	10%	9	Erie
R82	1M	1%	108	Erie
R83	150K	5%	109	Erie
R84	1M	1%	108	Erie
R85	330K	2%	109	Erie
R86	2.7K	5%	109	Erie
R87	270K	1%	109	Erie
R88	510K	5%	109	Erie
R89	820K	5%	108	Erie
R90	1.6M	1%	100	Erie
R91	220	10%	9	Erie
R92	22	10%	9	Erie
R93	1K	10%	9	Erie
R94	1M	1%	108	Erie
R95	2.2K	1%	P406	Painton
R96	1.3K	1%	108	Erie
R97	1.3K	1%	108	Erie
R98	880	1%	108	Erie
R99	880	1%	108	Erie
R100	150K	5%	109	Erie
R101	270K	1%	109	Erie
R102	1.33M	1%	74	Painton
R103	330K	2%	109	Erie
R104	2.7K	5%	109	Erie
R105	820K	5%	108	Erie

RESISTORS FIXED:

Circuit ref.	Value -Ohms	Tolerance ±	Manufacturer's Type No.	Manufacturer
R106	510K	5%	109	Erie
R107	1K	10%	9	Erie
R108	1.6M	1%	100	Erie
R109	220	10%	9	Erie
R110	22	10%	9	Erie
R111	1M	1%	108	Erie
R112	3.3K	1%	P406	Painton
R113	930	1%	108	Erie
R114	150K	5%	109	Erie
R115	270K	1%	109	Erie
R116	1.33M	1%	74	Painton
R117	330K	2%	109	Erie
R118	2.7K	5%	109	Erie
R119	820K	5%	108	Erie
R120	510K	5%	109	Erie
R121	1K	10%	9	Erie
R122	1.6M	1%	100	Erie
R123	220	10%	9	Erie
R124	22	10%	9	Erie
R125	1M	1%	108	Erie
R126	3.3K	1%	P406	Painton
R127	930	1%	108	Erie
R128	1.33M	1%	74	Painton
R129	330K	2%	109	Erie
R130	2.7K	5%	109	Erie
R131	150K	5%	109	Erie
R132	270K	1%	109	Erie
R133	820K	5%	108	Erie
R134	510K	5%	109	Erie
R135	1K	10%	9	Erie
R136	1.6M	1%	100	Erie
R137	220	10%	9	Erie
R138	1M	1%	108	Erie
R139	22	10%	9	Erie
R140	3.3K	1%	P406	Painton

RESISTORS FIXED:

Circuit ref.	Value -Ohms	Tolerance ±	Manufacturer's Type No.	Manufacturer
R141	1.33M	1%	74	Painton
R142	330K	[illegible]	109	Erie
R143	2.7K	[illegible]	[illegible]	Erie
R144	150K	[illegible]	[illegible]	Erie
R145	270K	[illegible]	109	Erie
R146	510K	5%	10[illegible]	Erie
R147	820K	[illegible]	10[illegible]	Erie
R148	1K	10%	[illegible]	Erie
R149	1.6M	1%	10[illegible]	Erie
R150	220	10%	[illegible]	Erie
R151	1M	1%	10[illegible]	Erie
R152	22	10%	[illegible]	Erie
R153	3.3K	1%	74[illegible]	Painton
R154	130K	1%	10[illegible]	Erie
R155	47K	1%	10[illegible]	Erie
R156	220K	5%	109	Erie
R157	1M	5%	10[illegible]	Erie
R158	1[illegible]K	2%	109	Erie
R159	1M	5%	10[illegible]	Erie
R160	1K	10%	9	Erie
R161	22	10%	9	Erie
R162	330K	2%	109	Erie
R163	10K	10%	8	Erie
R164	330K	2%	109	Erie
R165	150	5%	P306	Painton
R166	750	5%	P306	Painton
R167	750	5%	P306	Painton
R168	22	10%	8	Erie
R169	220	10%	9	Erie
R170	470K	10%	9	Erie
R171	39K	1%	108	Erie
R172	18K	1%	109	Erie
R173	12K	1%	109	Erie
R174	33K	1%	108	Erie
R175	100K	10%	9	Erie

RESISTORS FIXED:

Circuit ref.	Value -Ohms	Tolerance ±	Manufacturer's Type No.	Manufacturer
R176	22	10%	[illegible]	Erie
R177	1M	10%	[illegible]	Erie
R178	33K	5%	[illegible]	Morgan
R179	1K	10%	[illegible]	Erie
R180	1K	10%	[illegible]	Erie
R181	47	10%	[illegible]	Erie
R182	1.5K	5%	10[illegible]	Erie
R183	1.5K	5%	10[illegible]	Erie
R184	1.5K	5%	10[illegible]	Erie
R185	1.5K	5%	10[illegible]	Erie
R186	3.3	10%	[illegible]W1	Painton
R187	100	10%	[illegible]	Erie

RESISTORS VARIABLE:

Circuit ref.	Value -Ohms	Tolerance ±	Manufacturer's Type No.	Manufacturer
RV1	100K	10%	CLR4201/9S Linear	Colvern
RV2	2.5K	10%	CLR1206/9S Linear	Colvern
RV3	10K	10%	CLR4201/9S Linear	Colvern
RV4	5K	10%	CLR1206/9S Linear	Colvern
RV5	100K	10%	CLR4201/9S Linear	Colvern
RV6	2.5K	10%	CLR1206/9S Linear	Colvern
RV7	5K	10%	CLR1206/9S Linear	Colvern
RV8	5K	10%	CLR1206/9S Linear	Colvern
RV9	5K	10%	CLR1206/9S Linear	Colvern
RV10	5K	10%	CLR1206/9S Linear	Colvern
RV11	5K	10%	CLR1206/9S Linear	Colvern
RV12	5K	10%	CLR1206/9S Linear	Colvern
RV13	100/100	10%	CLR4210/9S Linear	Colvern
RV14	5K	10%	CLR1206/9S Linear	Colvern
RV15	100	10%	CLR1206/9S Linear	Colvern
RV16	100	10%	CLR1206/9S Linear	Colvern
RV17	5K	10%	CLR1206/9S Linear	Colvern
RV18	5K	10%	CLR1206/9S Linear	Colvern

CAPACITORS:

Tubular & Rectangular Metal Cased Capacitors:-

Circuit ref.	Value - uF	Tolerance ±	D.C. Wkg. Volts 71° C.	Manufacturer	Type
* C1	8	5%	600	Dublilier	Nitrogol B215
* C5	8	5%	600	Dubilier	Nitrogol B215
* C8	8	5%	600	Dubilier	Nitrogol B215
* C12	8	5%	600	Dubilier	Nitrogol B215
* C18	8	5%	600	Dubilier	Nitrogol B215
* C22	2	5%	600	Dubilier	Nitrogol B211
* C26	2	5%	600	Dubilier	Nitrogol B211
* C30	2	5%	600	Dubilier	Nitrogol B211
* C34	2	5%	600	Dubilier	Nitrogol B211
C42	1	20%	600	T. C. C.	Visconol CP142T
C43	8	20%	600	T. C. C.	Visconol CP150T
C44	8	20%	600	T. C. C.	Visconol CP150T
C45	.01	25%	350	T. C. C.	Metalmite CP32N Slvd.
C46	.01	25%	350	T. C. C.	Metalmite CP32N Slvd.
C47	.01	25%	350	T. C. C.	Metalmite CP32N Slvd.
C48	1	25%	250	Hunts	W49 B50SP

* In some instruments, due to poor component delivery, selected wider-tolerance capacitors have been used. In these cases, the measured capacity is marked on each capacitor. In the event of failure of a capacitor, it should be replaced by a similar component having a capacity within ± 5% of the marked value.

CAPACITORS:

Ceramic & Polystyrene Capacitors:-

Circuit ref.	Value - pF	Tolerance ±	Wkg.Volts D.C.	Manufacturer	Type
VC1	10-100	+80% -0	350	T.C.C.	TCK 1010
C2	150	5%	500	Suflex	HS2206/500V
C3	10	5%	750	Erie	N.750.K
C4	10	5%	750	Erie	N.750.K.
C6	10	5%	750	Erie	N.750.K
C7	10	5%	750	Erie	N.750.K
C9	10	5%	750	Erie	N.750.K
C10	33	5%	750	Erie	N.750.K
C11	10	5%	750	Erie	N.750.K
C13	150	5%	500	Suflex	HS2206/500V
C14	10	5%	750	Erie	N.750.K
C15	10	5%	750	Erie	N.750.K
C16	4.7	0.5pF	750	Erie	P.100.K
C17	4.7	0.5pF	750	Erie	P.100.K
C19	10	5%	750	Erie	N.750.K
C20	33	5%	750	Erie	N.750.K
C21	10	5%	750	Erie	N.750.K
C23	10	5%	750	Erie	N.750.K
C24	33	5%	750	Erie	N.750.K
C25	10	5%	750	Erie	N.750.K
C27	10	5%	750	Erie	N.750.K
C28	33	5%	750	Erie	N.750.K
C29	10	5%	750	Erie	N.750.K
C31	10	5%	750	Erie	N.750.K
C32	33	5%	750	Erie	N.750.K
C33	10	5%	750	Erie	N.750.K
C35	10	5%	750	Erie	N.750.K
C36	33	5%	750	Erie	N.750.K
C37	10	5%	750	Erie	N.750.K
C38	10	5%	750	Erie	N.750.K
C39	270	5%	500	Suflex	HS2206/500V
C40	10	5%	750	Erie	N.750.K
C41	10	10%	500	Suflex	HS2206/500V

VALVES:

Circuit ref.	Type	Manufacturer
V1	6BS7	Brimar
V2	12AX7	Brimar
V3	6BS7	Brimar
V4	12AX7	Brimar
V5	12AX7	Brimar
V6	12AX7	Brimar
V7	12AX7	Brimar
V8	12AX7	Brimar
V9	12AX7	Brimar
V10	12AX7	Brimar
V11	N78	Osram
V12	12AX7	Brimar
V13	N78	Osram
V14	12AX7	Brimar
V15	N78	Osram
V16	12AX7	Brimar
V17	N78	Osram
V18	12AX7	Brimar
V19	N78	Osram
V20	12AX7	Brimar
V21	N78	Osram
V22	53KU	Cossor
V23	12E1	Mazda
V24	Z77	Osram
V25	85A2	Mullard
V26	12AT7	Brimar

SPECIAL COMPONENTS:

Circuit Ref.	Component	Supplier	Type
L1	10H/18mA Choke	Parmeko	Ref. No. P463 Model 5080/10
T1	Transformer	Parmeko	'Solatron' Spec. 295003
M1	Thermocouple Wattmeter	Sangamo Weston	'Solatron' Spec. B6023
M2	Thermocouple Wattmeter	Sangamo Weston	'Solatron' Spec. B6024

SECTION 6

SETTING UP PROCEDURE

Notes:-

1) Solartron instruments used in the setting up and test procedure are:-

   (a) Feedback Voltmeter, Model VF252

   (b) L.F. Decade Oscillator, Model OS103.

2) The thermocouple voltmeters used in the L.F. Resolved Component Indicator are very susceptible to burn out when overloaded and it is recommended that, for initial testing and adjustment of a unit, each meter be replaced by a Wheatstone bridge where each arm is a 110Ω ¼ watt resistor.

3) Whenever a C.R.O. Feedback Voltmeter, or similar measuring instrument is connected to the internal circuitry of the L.F. Resolved Component Indicator, it is recommended that the connection be made through a 4.7KΩ buffer resistor, to prevent capacity loading which may result in parasitic oscillation.

PROCEDURE:

(1) Preparation

a) Turn all pre-set potentiometers to approximately mid-position.

b) To obviate the difficulty of setting D.C. levels when large time constants are in circuit, 0.1mfd. 250v.w. capacitors should be connected in series with C5, C8 and C18.

c) The earthing switch should be set to the DIRECT position, if an earth is not provided by external equipment connected to the Resolved Component Indicator.

d) The instrument should be set to Balanced 150 volt sensitivity.

e) Measure the mains voltage and set mains tap accordingly.

(2) H.T. and 70v Rail

Making connection at the power unit output terminals, set the H.T. Rail to 250 volts, using a Model 9 Avometer, by adjusting RV14. Connect a C.R.O. to the terminals, to ensure that the H.T. rail is free from parasitic oscillation.

Measure the total hum and noise level, using the Feedback Voltmeter. It should be of the order of 600μV r.m.s.

Making connection at the output of the 70v Rail Unit, set the rail to 70 volts by adjusting RV13. Check that there are no parasitic oscillations and measure the total hum and noise. It should be of the order of 400μV r.m.s.

(3) Quiescent Levels

Connect a C.R.O. to the cathode of V11 to indicate any parasitic condition in the following procedure. Adjust the following valve cathodes to zero volts with respect to the 70 volt rail, using a Model 9 Avometer connected between the points and the 70 volt rail.

Point	Adjustment potentiometer
V 2 pin 3	RV 1
V 4 pin 3	RV 5
V 6 pin 8	RV 2
V11 pin 2	RV 4
V13 pin 2	RV 7
V15 pin 2	RV 8
V17 pin 2	RV 9
V19 pin 2	RV10
V21 pin 2	RV11

Remove the 0.1μF capacitors connected in series with C5, C8 & C16.

(4) Hum Level of Signal Channel

With the inputs open circuit and the input attenuator in the 50mV position, adjust hum-balancing potentiometers RV15, RV16 to give minimum hum level at V11 cathode. It should be of the order of 12mV r.m.s. A similar level should exist at V13 cathode.

(5) Reference Drive Amplifiers

Feed in 1½ volts/80 c/s. to the input of each reference drive amplifier in turn. Examine the signal at the point mentioned below and ensure that it is free from distortion, parasitic oscillation and hum. The gain of each amplifier from input to the point mentioned should be unity ± 2%.

Amplifier Input	Measurement Point
0°	V15 pin 2
180°	V17 pin 2
90°	V19 pin 2
270°	V21 pin 2

(6) Signal Gain

Apply a 50mV/80 c/s. signal to the 0° signal input. Switch to the "Unbalanced" condition and adjust RV3 to give 6.5V r.m.s. on V11 cathode. A similar level should appear at V13 cathode. Both voltage levels should be set with the Feedback Voltmeter.

(7) Balance

Switch to the "Balanced" condition, and apply the 50mV/80 c/s. signal to both 0° and 180° inputs simultaneously. Adjust RV6 to give minimum signal at V11 cathode. This minimum should be of the order of 30mV r.m.s.

(8) Signal Distortion and Overdrive

Break the 2+ and 2- connections to the reference meter bridge and connect in place a thermocouple type milliammeter, preferably of 12mA full scale sensitivity. Connect a C.R.O. to the cathode of V11, set the signal sensitivity to 5 volts, and apply an 80 c/s signal. Increase the signal until peak distortion is just apparent as viewed on the C.R.O. The milliammeter must then indicate at least 8mA. Repeat the procedure, viewing at V13 cathode, and again the current must be at least 8mA. Now increase the input voltage, and increase the signal sensitivity until a maximum current is indicated. This maximum should be less than 12mA.

Re-connect the 2+ and 2- leads and insert the milliammeter in the quadrature meter 2+ and 2- connections. Repeat the above procedure, noting again that the maximum undistorted current shall be 8mA and the maximum current less than 12mA.

(8) contd.

Replace the 1+ and 1- connections to the reference meter resistance bridge.

(9) Reference Distortion and Overdrive

Break the 1+ and 1- connections to the reference meter resistance bridge, and connect in place a thermocouple milliameter of 20mA full scale sensitivity. Connect a C.R.O. to V17 cathode, and apply a balanced 20V c.w. signal to the 0° and 180° reference inputs. Increase the signal until peak distortion is just apparent as viewed on the C.R.O. The milliammeter must then indicate at least 11mA. Repeat viewing at V17 cathode, and again the current must be at least 11mA. Now increase the input voltage until a maximum current is reached; this current should be less than 15 mA.

Replace the 1+ and 1- connections to the reference meter resistance bridge, and insert the milliammeter in the 1+ and 1- connections to the quadrature meter. Connect the C.R.O. to V19 cathode, and apply the 20V c.w. signal to the 90° and 270° reference inputs. Repeat the above procedure, viewing first at V19 cathode and then V21 cathode.

(10) Meter Datums

At this stage, the resistance bridges should be replaced by the actual thermocouple wattmeters. Before the instrument is switched on, care should be taken to ensure that the mechanical zero adjustments of the meters are correctly set.

Apply a balanced 20V/90 c.w. signal (i.e. 10V/phase) to the 0° and 180° reference inputs. Switch the signal input to the "UNBALANCED" 150W sensitivity and adjust RV17 for zero indication on the reference meter.

Now apply the balanced signal to the 90° and 270° reference inputs and adjust RV18 for zero indication on the quadrature meter.

(11) Signal Sensitivity

Apply a balanced 20V/80 c/s. signal to the 0° and 180° reference input. This input should be set accurately, using a Feedback Voltmeter. Switch to 1V signal sensitivity, and connect the 0° signal input to the 0° reference input terminal. Adjust RV3 until an indication of 10 volts is registered on the "IN PHASE" side of the reference meter.

Now apply the balanced signal to the 90° and 270° reference inputs, and adjust RV13 until an indication of 10 volts is registered on the "LEAD" side of the quadrature meter.

(12) Phase Compensation

Apply a 10V/ phase 4-phase reference input, preferably from Oscillator O.P.103. Set the Oscillator to 1 Kc/s frequency, and apply a 10V signal to the 0° signal input terminal. The signal sensitivity should be set at 15 volts "UNBALANCED". Set the quadrature meter to zero, using trimmer VC1. It may be found necessary to increase C6 within the range 10 - 120pF to achieve the zero condition.

SECTION 7

PERFORMANCE TESTS

(1) Range Coverage

Apply a 10V/80 c/s. four phase reference input from an Oscillator OS.103, using the cable provided. Utilising the attenuator in the oscillator, check the sensitivity ranges of the Resolved Component Indicator after allowing a 15 minutes warm-up period.

(2) Balanced Input

Apply a four phase reference input of 10V/80 c/s. from an Oscillator OS.103. Check that a 4V/80 c/s. balanced signal gives twice the indication of a 4V/80 c/s. unbalanced signal.

(3) Rejection of off-tune frequencies

Apply a four phase reference input of 10V/80 c/s. from an Oscillator OS.103. From a second oscillator, apply a 10V/120 c/s. signal to the 0° signal input, using the 15 volt "UNBALANCED" sensitivity. Note that the indication on either meter is less than 0.1 volt.

(4) Frequency Coverage

Apply a 10 volt four phase reference input from an Oscillator OS.103, using the cable provided. Apply to the 0° signal input, using the 15 volt "UNBALANCED" sensitivity, a 10 volt signal at 80 c/s. Adjust the output amplitude of the Oscillator until the Resolved Component Indicator reads precisely 10 volts. Note the reading on the Oscillator meter. Maintain the Oscillator amplitude at this value whilst varying the frequency over the range 0.5 c/s. to 1 Kc/s. Note that the Resolved Component Indicator indication should not vary by more than $\pm$ 3% of full scale.

(5) Self-heating Error

Apply a 10 volt/80 c/s. four phase reference input from an Oscillator OS.103, using the cable provided. Apply to the 0° signal input a 10 volt in phase signal from the Oscillator. Monitor the Oscillator output with a Feedback Voltmeter.

(5) contd.

Switch on and allow a 15 minute warm-up period. Then adjust the Oscillator output to 10 volts precisely on the Feedback Voltmeter, note the Resolved Component Indicator reading.

Leave the instrument in operation for three hours and, after ensuring that the applied input is still 10 volts, note the new reference meter indication. The change in indication should be less than 2% of full scale.

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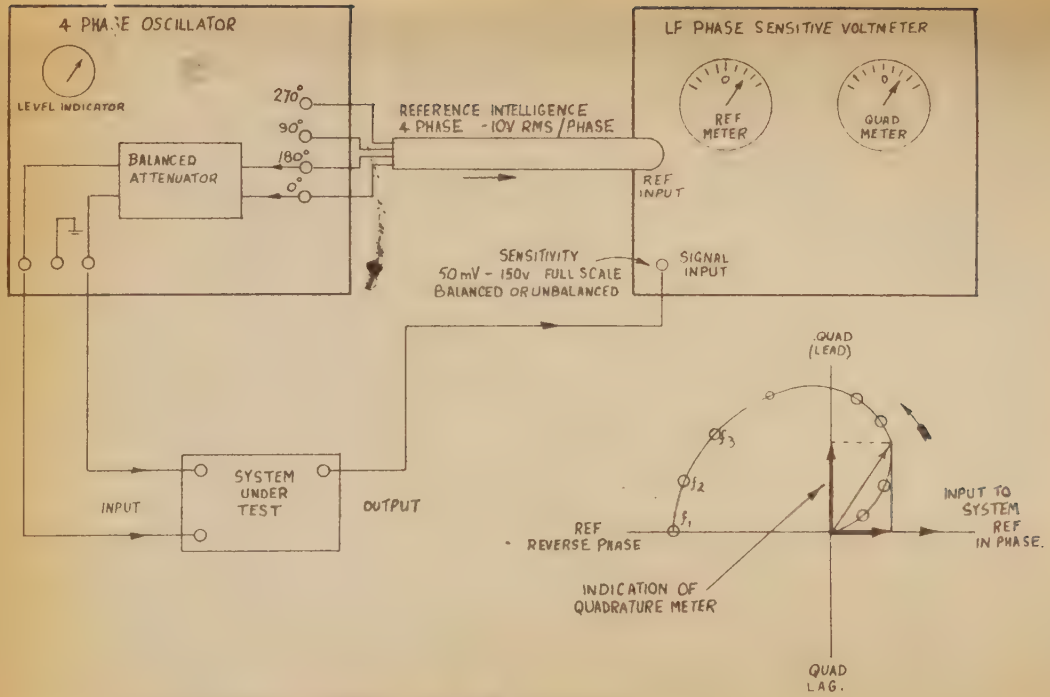
APP



BLOCK DIAGRAM - TRANSFER FUNCTION ANALYSER

FIG - 1.

SOLARTRON

TITLE –

DRN.

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LG'KS

DRG.No. A 14054 SHEET 4 of

OPERATING INSTRUCTIONS

Whatever the application of the Resolved Component Indicator, there is a certain procedure and several precautions which should be strictly adhered to.

(i) Mechanical zero of meters

When the Resolved Component Indicator has been placed in the position in which it is intended for use, the mechanical zero adjustments for the two meters should be correctly set before the instrument is switched on.

(ii) Connections to the Resolved Component Indicator

It is recommended that one earth connection only be made from the work on test to the Resolved Component Indicator earth terminal, in order to eliminate the possibility of error voltages arising from loop currents. Further, when either the work, or any auxiliary equipment connected to the work, has a direct earth connection, the Resolved Component Indicator should be set to 47Ω earth. This connects a 47Ω resistor between the negative rail of the instrument and the mains earth, hence, eliminating once again a possibility of loop current. When the equipment connected to the Resolved Component Indicator is fully isolated, the above-mentioned switch should, of course, be set for direct earth.

The choice of using either shielded or unshielded connecting wires will, in each case, be dependent upon the frequency, impedance and relative amplitude levels in the circuits supplying the Resolved Component Indicator. When operating at low level on high impedance systems, it is essential that shielded cable be employed, otherwise pick-up signals in excess of the working signals may fully load the Resolved Component Indicator. On the the other hand, if shielded cable is employed at high frequency the stray capacitance of the cable may well result in unwanted phase shift in the circuit under test. In every case, therefore, the above-mentioned points should receive careful consideration.

When shielded cable is employed, it is advised that the braiding be cut back at the free ends and a single earth wire be run from the Resolved Component Indicator earth terminal, thus protecting against loop currents.

(iii) Initial Preparation

Open the small door on the right-hand side of the instrument case and remove the cables stowed within. Set the mains adjustment panel inside the door to the voltage of your supply. Fig. 4. shows a typical operational set-up.

Connect up the reference input, using either the terminals or the Breeze socket provided, to its four phase supply. (If 'Solartron' Oscillator OS.103 is used, the connection may be made with the cable provided). Each phase of the energisation should have a level of 10 volts r.m.s. with respect to ground, and should be sinusoidal in form. The input impedance is 1.33MΩ per phase, and each input is D.C. blocked by a 2μF 600 volt working capacitor. The accuracy of indication of the Resolved Component Indicator will depend on the accuracy and stability of the reference energisation. In general, the reference inputs should be accurate and maintained to ± 1% of 10 volts.

The signal input, which has an input impedance of 1MΩ per phase, is D.C. blocked by 8μF 600 volt working capacitors. The signal voltage applied to the Low Frequency Resolved Component Indicator must be either unbalanced with respect to ground, or balanced about ground.

The blocking time constants used in the instrument are, in view of the low frequencies at which this equipment operates, necessarily long.

Consider, for instance, the case where a 1V AC signal, superimposed on a 200V quiescent component, is to be measured. If this voltage were directly applied to the Resolved Component Indicator, the 200V step component would cause overload and paralysis of the Resolved Component Indicator for a period of time in the order of 1 minute. To overcome this difficulty, a priming position is provided on the Resolved Component Indicator range selector, where the operative time constant is shortened in order to charge the blocking capacitor in a much reduced period of time. When connecting a signal where a large quiescent voltage is known to be present, the instrument should first be switched to the prime condition, the signal applied, and the range selector then set to the desired sensitivity.

(iv) Ranging of Low Frequency Resolved Component Indicator

It is recommended that the instrument be ranged to a lower sensitivity at the indicating levels where the sum of the indications is approximately equal to full scale. If the

(iv) contd.

instrument is operated such that the indications of the two meters are simultaneously near full scale, a slight reduction in sensitivity will result. This is due to self-heating errors in the instrument thermocouples.

(v) Overload of Low Frequency Resolved Component Indicator

The drive amplifiers for the thermocouple wattmeters have overload protection, which ensures that application of even the most excessive overload will not result in burn out. However, the instrument should not be left for more than 30 seconds with either indicating meter reading in excess of full scale, otherwise ageing of the thermocouple elements may result, with a consequent slight change in sensitivity.

(vi) Operation under conditions of poor signal/noise ratio

Providing that the signal to harmonic/spurious frequency ratio is at least 2:1 in favour of the desired signal, negligible error will result from the presence of such components. When the signal/noise ratio is in the order of 1:1 or worse, it is essential that the instrument be operated at comparatively small indications on the meters, otherwise the harmonic or spurious components may bring the protective limiters into operation, and consequently give incorrect indications.

In cases where it is known that large values of harmonic or spurious components are likely to be present, it is recommended that a cathode ray oscillograph be utilised in parallel with the Resolved Component Indicator signal input, in order that the operator may be aware of this condition and take the necessary precautions.

(vii) Operation at frequencies below .5 c.p.s.

The nominal frequency range for the Low Frequency Resolved Component Indicator is .5 c.p.s. to 1 K.c.p.s. It should be realised that operation of the Resolved Component Indicator outside the stated range will result in increasing errors.

The following table gives the maximum phase and amplitude errors, due to blocking compononts, at frequencies between .5 c.p.s. and .1 c.p.s.

(vii) contd.

Frequency	Max. Phase Error	Sensitivity Error (low)
.5 c.p.s.	.8°	1%
.4 c.p.s.	1°	1.5%
.3 c.p.s.	1.5°	3%
.2 c.p.s.	2°	6%
.1 c.p.s.	5°	20%

At frequencies below .5 c.p.s. the indicating meters will respond within the cycle, and at .1 c.p.s. it will be found that there is a considerable peak to peak swing.

It is recommended that, before using the instrument outside its nominal range, a check on the phase shift and sensitivity error be made, by connecting a known signal directly from the Oscillator to the Resolved Component Indicator. This check also reduces errors which may arise through reading the mean value of pointer excursion.

(viii) Effect of temperature on the Indicating Meters

The wattmeters employed in the Resolved Component Indicator utilise thermocouple elements, and consequently there will be a loss of sensitivity with increasing ambient temperature.

The extent of the sensitivity error is in the order of 0.2% per °C. The instruments are calibrated at a nominal room temperature of approximately 25°C and consequently operation at a temperature of 35°C will give an error in the order of 2%.

This temperature error applies only as far as absolute voltage measurement is concerned, and where transfer function is to be plotted its effect will be negligible.

(ix) Procedure

The usual procedure for testing is to apply a constant input voltage to the system under test, as determined by the Oscillator output attenuator, and to plot at a number of suitably chosen frequencies the resolved components of the

(ix) contd.

voltage present at the selected point in the test system. Providing that the input voltage for the work is maintained constant throughout the test, results may be directly plotted in typical form, using cartesian co-ordinates.

THIRD ANGLE PROJECTION

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